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ABSTRACT

This study filmed a transcription typist and analyzed the finger movements in the resulting motion picture to study how skilled motor movements are programmed and controlled. Findings indicated that a typist's finger movements usually overlapped in time, and the starting times of these movements were highly variable, even when comparing identical sentences. Movements toward keys were often initiated out of the order in which the letters were eventually typed. These results conflict with current models of rapid, well-learned motor movements and suggest instead a multi-level control of movement utilizing feedback or prediction. (IRA)

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Finger Movements in Transcription Typing

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Abstract

Skilled transcription typing is normally thought to involve highly routinized, sequential movements. However, high-speed films show that a typist's finger movements usually overlapped in time, and the starting times of these movements were highly variable, even when comparing identical sentences. Movements toward keys were often initiated out of the order in which the letters were eventually typed. These results conflict with current models of rapid, well learned motor movements and suggest instead a multi-level control of movement utilizing feedback or prediction.

Rapid, precise, malleable motor activity as demonstrated in speech and manual tasks is an important human characteristic. The task of typing, because it is an extremely rapid skill (a good office typist will average seven or eight keystrokes per second) and has a well defined output, has been the subject of speculation and some investigation (Lashley, 1959; Shaffer, 1973; Sternberg, Monsell, Knoll & Wright, 1973). Typing has typically been thought of as a sequential, automatic process. Models of the motor output generally involve a series of motor commands, often one for each letter, which are placed in a buffer and then sequentially executed. The actual finger movement is assumed to be ballistic with no feedback control once the movement is initiated. Accordingly, studies of typing have been almost exclusively based on records of the keys pressed and the inter-keypress latencies (Sternberg et al., 1978; Shaffer, 1976).

A proper test of the ballistic sequential model requires a more detailed examination of the typing process. In order to study how skilled motor movements are programmed and controlled, we filmed a transcription typist and analyzed the finger movements in the resulting motion picture. The data reported here are based on a high-speed (100 frames per second) film of an expert typist. The typist transcribed English sentences on the typewriter-like keyboard of a computer terminal at approximately 90 words/minute. For each such keystroke, we determined the time at which the finger started a smooth movement toward the key. During the filming, the keypresses and inter-keypress latencies were recorded by computer .[1]

We found that 96% of the finger movements were initiated before the previous key was pressed. The mean time for a complete finger movement was 261 msec, while the mean inter-keypress latency was 124 msec. Thus two or three fingers are often in motion simultaneously.

Insert Figure 1 about here

These data are expanded in Figure 1 which shows the distribution of the starting and ending times of finger movements, both measured relative to the time when the previous key was pressed. This figure shows that the starting times of finger movements are more variable than their ending times (the keypresses). The starting times have a standard deviation of 103 msec, while the ending times have a standard deviation of 26 msec.

Insert Figure 2 about here

Figure 2 illustrates this result, showing the timing of keystrokes for two words from a pair of repeated sentences. Figure 2 also shows two cases where the keystrokes are initiated in an order different from the final keypresses. Overall, 21% of the movements were initiated out of order (although the movements always ended with keypresses in the correct order). There were several cases where the finger movements were initiated out of order by 150 msec or more. Movements were initiated out of order for sequences of letters occurring both within hands (24% of the time) and across hands (13% of the time). One case, shown in the top portion of Figure 2, extended over two words: In typing the

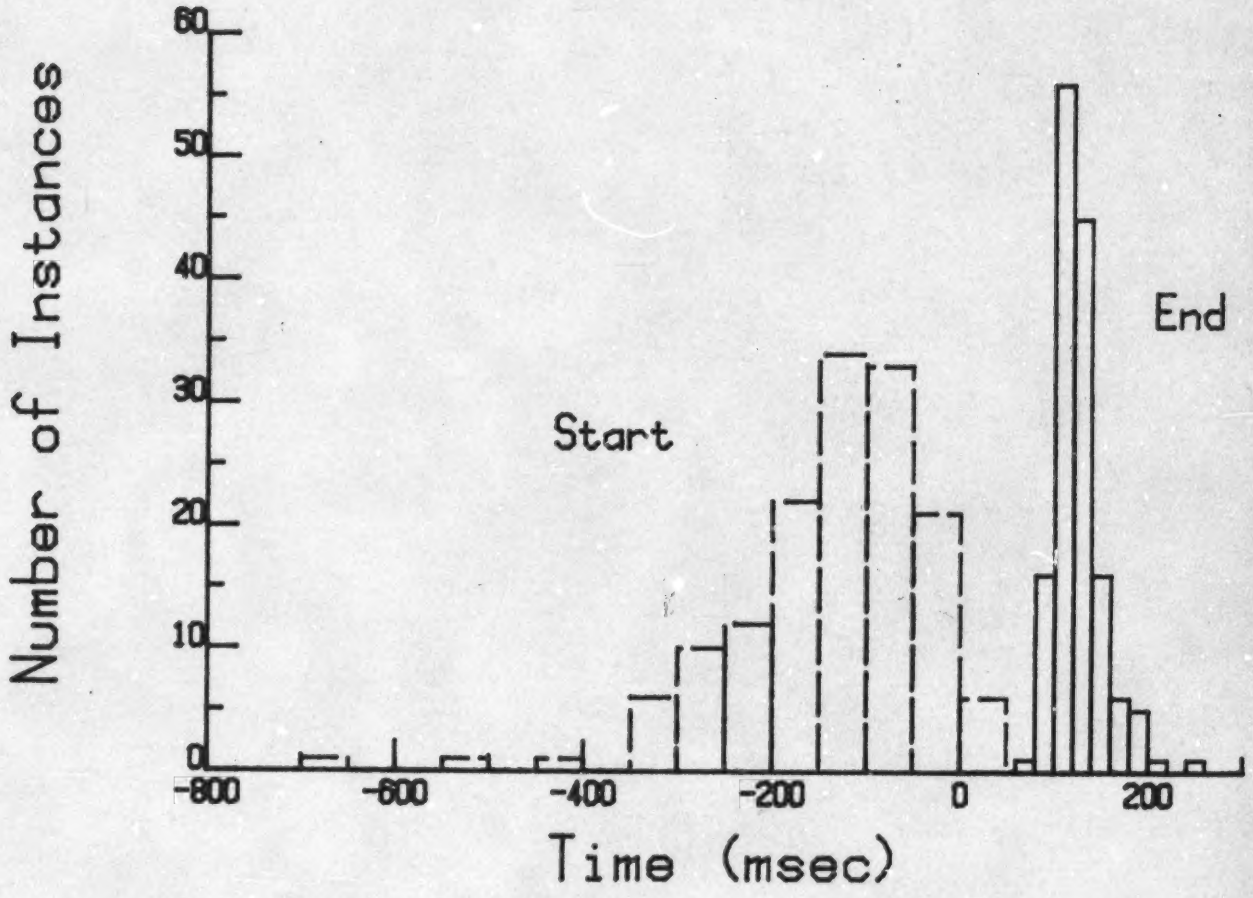

Figure 1. The distribution of starting and ending times of keystrokes, measured relative to the time of the previous keypress. Most keystrokes overlap, with the second finger movement starting before the keypress at the end of the previous movement. The starting times of movements show much more variability than the ending times.

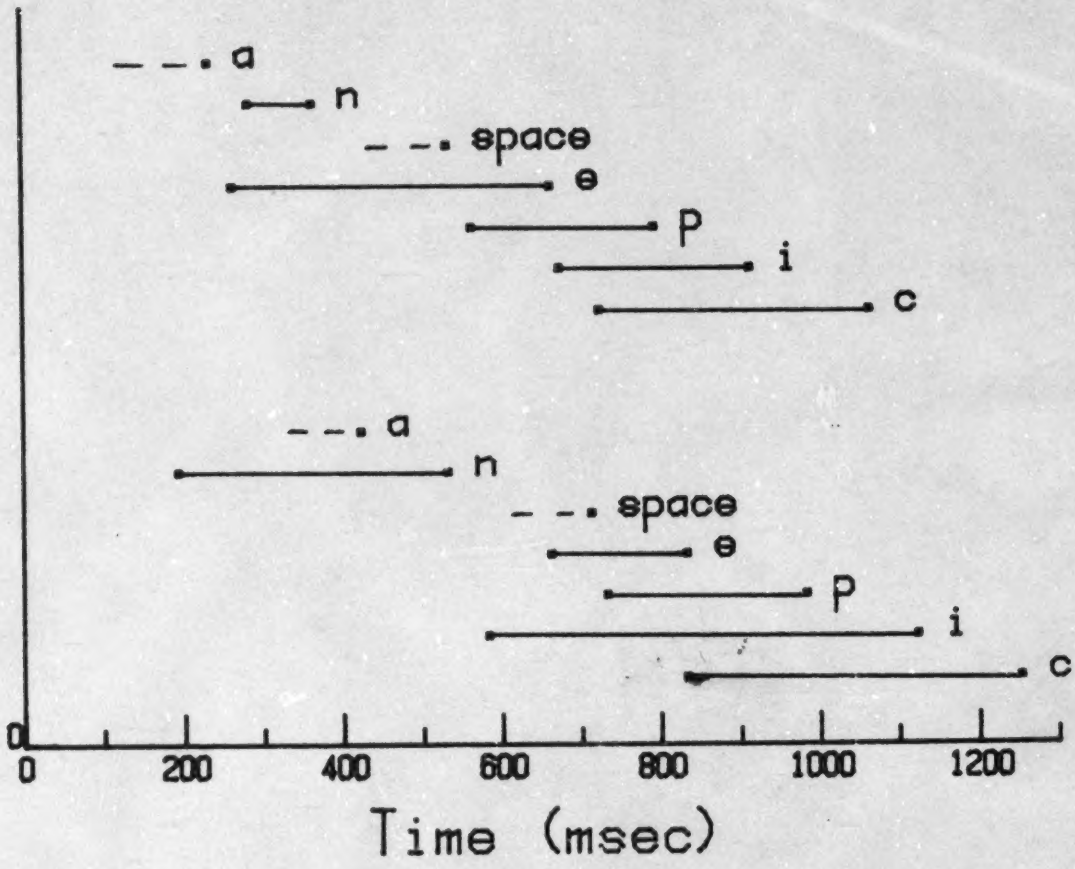

Figure 2. Relative timing of keystrokes for the phrase "... an epic ..." on repeated typing of the same sentence. The left ends of the horizontal lines represent the initiation time of the keystrokes, and the right ends of the lines represent the time of the keypresses. Initiation times were not measured for the letter a and the space bar; this is indicated by the dashed lines to the left of the keypress times. Note that successive keypresses are more regularly timed than the corresponding initiations. In two cases, although the keys were pressed in the proper order, the keystrokes are initiated out of order: in the first sentence the a keystroke was initiated before that of n in the previous word; in the second sentence the keystrokes for the word epic were initiated in the order i, e, p, c.

sequence an epic, the movement to type the e was initiated before the movement to type the n.

These data raise two questions: 1) What is responsible for the large variation in movement times? 2) How are the movements controlled so that the inter-keypress latencies are much more regular than the starting times of the movements?

We found that the movement times were partly determined by the length of time that the corresponding hand and finger had been free. Depending on the sequence of letters being typed, a given hand may be free for varying times before it presses a key, and we found that the longer the hand was free the earlier the keystrokes were initiated. This is undoubtedly related to the common observation that sequences of letters which alternate between the hands are typed faster than sequences which are typed with a single hand. However, we found that finger movements within one hand can also overlap. In 51% of the cases where successive keys were typed by two fingers on the same hand, the second keystroke was initiated while the first keystroke was still in progress. Early initiation of the second keystroke was positively correlated with the length of time that finger had been free. The analyzed film included two repeated sentences. Comparison of these sentences demonstrated that the particular letter or pattern of letters being typed accounts for only part of the variation in movement times. The movement times to type a given letter in identical contexts had a correlation coefficient of 0.60; that is, only about 35% of the variance is related to the letter being typed and the sentence context. The por-

tion of the variance associated with the letter being typed and its context can be traced almost entirely to the length of time that the corresponding finger and hand have been free.

The remaining variance in movement time (65%) indicates that the automated finger movements in touch typing are not entirely stereotyped or preprogrammed; the movement appears to be controlled during its execution. Just as we observed with the overall data, the variation in movement times on repeated typing is due primarily to variation in starting times. Measured relative to the previous keypress, the median difference in starting times was 58 msec, while the the median difference in ending times (the inter-keypress latency) was 10 msec. Figure 2, which shows the timing for repeated typing of the phrase, an epic, illustrates this finding by contrasting the irregularity of the initiations of finger movements with the regularity of the keypresses. Overall, comparing corresponding letters in the repeated sentences, earlier starting times for a movement were not correlated with shorter inter-keypress latencies ($r = 0.05$). An analysis of corresponding keystrokes in the repeated sentences showed that there can be significant variation in the finger's position at the start of the keystroke. In particular, keystrokes which start with the finger closer to the target key are initiated later than keystrokes starting farther away.

There is precedent for the notion that highly skilled sequential movements can overlap. An analogous phenomenon is well known in phonology, where the articulatory movements required for a sequence of phonemes often overlap in time (Perkell, 1969). The great variability

in initial finger position, initiation and movement times, and the existence of frequent initiations out of order, however, present difficulties for existing models which call for sequential keystroke initiation. Models which view the output process in typing as the execution of a series of motor programs, one for each letter, cannot account for these observations. Our results indicate that the motor program must be considerably more general, perhaps specifying only the key to be pressed, the finger, and its sequential relation to the other keypresses (Saltzman, 1979). Thus at this level the program appears quite abstract.

The actual initiation and timing of the movement and control of its trajectory might then be determined by a lower level of processing which takes into account the position of the fingers and the other competing activities. These processes controlling finger movement presumably utilize detailed information about the location and activities of the fingers. Sensory information and proprioceptive feedback from the muscles controlling the fingers could play a role. Neural impulses take about 70 msec to travel from muscle sensors through the cerebellum and back to the finger (Bizzi, 1979), an appreciable fraction of the movement times. Other control mechanisms are possible, however: For instance, control could be based on central monitoring of motor commands, rather than feedback from the fingers.

Regardless of the specific interface between the high-level program and the sequence of muscle movements, the picture of typing which emerges is very different from that of a stereotyped, ballistic movement.

References

Bizzi, E. Personal communication, June, 1979.

Lashley, K. S. The problem of serial order in behavior. In L. A. Jeffress (Ed.), Cerebral mechanisms in behavior. New York: Wiley, 1951.

Perkell, J. Physiology of speech production: Results and implications of a quantitative cineradiographic study. Cambridge, Mass.: MIT Press, 1969.

Saltzman, E. Levels of sensorimotor representation. Journal of Mathematical Psychology, 1979, 20, 91-163.

Shaffer, L. H. Latency mechanisms in transcription. In S. Kornblum (Ed.), Attention and Performance IV. New York: Acedemic Press, 1973.

Shaffer, L. H. Intention and Performance. Psychological Review, 1976, 83, 375-393.

Sternberg, S., Monsell, S., Knoll, R. L., and Wright, C. E. The latency and duration of rapid movement sequences: Comparisons of speech and typewriting. In G. E. Stelmach (Ed.), Information processing in motor control and learning. New York: Academic Press, 1978.

Footnotes

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1. The film which we have analyzed in detail covers 310 keystrokes (about 40 seconds of typing). Because we were primarily interested in the possibility of overlapping keystrokes, this analysis does not include keystrokes where successive keys are typed by the same finger, since the finger movements are necessarily sequential; in addition, the initiation of a movement toward a home row key is ambiguous, as it may simply be a return of the finger to a home position. Thus, we restricted our analysis of the film to the 147 keystrokes to letters on the upper or lower rows of the keyboard where the previous keystroke was not made by the same finger. Other films of the same typist and video tapes of other typists show results similar to those reported here, but they have not been analyzed quantitatively.

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